WORKING PAPER
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RATES OF RETURN AND CAPITAL AGGREGATION
USING ALTERNATIVE RENTAL PRICES

by

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WP# 1858-87   January 1987

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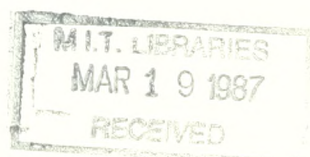USING ALTERNATIVE RENTAL PRICES

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November 1985
(Revised, January 1987)

1. INTRODUCTION

The publication by the U.S. Bureau of Labor Statistics (BLS) of multifactor productivity growth estimates for major U.S. sectors and industries (BLS [1983]) reflects an important research theme in the modern theory and measurement of economic cost and production. Until then, the BLS productivity program had focussed almost exclusively on labor productivity -- units of output per unit of labor. Increasingly, however, productivity researchers have been concerned with developing more comprehensive measures that reflect changes in output versus changes in all inputs -- units of output per unit of aggregate input. While BLS has contributed to and monitored these research efforts, in the late 1970s an independent review of productivity research was provided by a National Academy of Sciences Panel [1979] which then recommended that BLS undertake to develop and publish multifactor productivity measures for the United States. BLS [1983] is, therefore, the first result of an expanded BLS productivity measurement program, including both labor and multifactor productivity statistics.

The conceptual framework for a measure of multifactor productivity (MFP) is due to Jan Tinbergen [1942] and Robert Solow [1957]. In their formulation, MFP growth is related to outward shifts in the aggregate production function, and -- under certain conditions -- can be computed as growth in aggregate output minus growth in aggregate input, where growth rates in aggregate output and input are computed as the cost share-weighted growth rates in the components of output and input. The key assumptions required to compute the MFP measure directly from observable data are (i) that production technology is characterized by constant returns to scale; (ii) that output prices equal marginal production costs; (iii) that inputs are purchased in competitive markets; and (iv) that input quantites adjust instantaneously to their long-run equilibrium levels. Significant violation of any of these assumptions implies that more complicated models of

production are required, and that econometric methods must be employed in obtaining MFP measures.

The above discussion dramatizes the difficult task that economic theorists have set for economic statisticians, namely how to measure and/or impute the price and quantity components of outputs and inputs required to compute the cost share weights used in calculating aggregate output and input. The history of both conceptual and empirical research on MFP measurement since Solow [1957] is almost entirely taken up with this task. And of all the difficult problems, perhaps the most troublesome -- and the subject of the present paper -- has been the measurement of capital input service prices.

The basic issue in measuring capital input service prices is that capital goods are durable, and since rental markets for most durable inputs are not sufficiently widespread, it is usually not possible to observe the appropriate service price as the result of a market transaction. Under these conditions, the economic statistician must appeal to the theorist for assistance in deriving a rental price formula sufficient to impute rental prices for capital assets from observable data. These imputed rental prices can then be combined with estimates of capital input service flows to calculate the rental cost share weights required to compute the aggregate capital services.

While economic theory has provided important guidance in the specification of rental price formulae, it as yet has not been able to resolve completely all the empirical questions that the economic statistician must answer. Most importantly, two critical components of the asset-specific rental prices are: (i) the expected rate of return, and (ii) the expected capital gains terms. Empirical implementation of these expected rates of return and capital gains components typically requires making certain choices about which economic theory offers little guidance. For example, are expectations on capital gains myopic, are they perfectly anticipated, or are they a weighted average of recent asset-

specific capital gains experiences? Whatever choice is made in the empirical

implementation, it is clear that the resulting measures of aggregate capital

input growth and, therefore, MFP growth, will be affected.

The empirical effects of alternative capital rental price formulae have

been investigated elsewhere in the economic literature. For example, Dale

Jorgenson and Calvin Siebert [1968a,b] have considered alternative rental price

formulations in explaining investment behavior for individual firms in the

1950's and 1960's. Ernst Berndt [1976] has shown that much of the apparent

disparity in studies of capital-labor substitution elasticities in the 1960s and

early 1970s could be reconciled by recognizing that different capital rental

price measures were being employed. Michael Hazilla and Raymond Kopp [1984]

have explored the effects of alternative capital rental price measures on

econometric, parametric productivity growth measures for two-digit manufacturing

industries, 1958-77.

Capital rental price measurement was also a prominent issue in the famous

"productivity growth measurement debate" between Edward Denison, and Dale

Jorgenson and Zvi Griliches. In their classic article, Jorgenson and Griliches

[1967] employed an annual adjustment for asset appreciation -- capital gains due

to inflation effects -- in their measure of the capital service price. Denison

[1969, p. 45] argued that incorporating long-term averages of capital gains

"might be appropriate," but that use of annual capital gains calculations was

dubious, "since capital gains are highly erratic from year to year."[1] In

responding, Jorgenson and Griliches [1972, p. 70] noted that the capital gains

adjustment was logically implied by their use of the perpetual inventory method

for measuring net capital stock, leaving open the empirical possibility of

incorporating capital gains by means other than annual adjustments, e.g., some

variant of Denison's idea of "long term averages of capital gains."

In this paper we continue empirical research on evaluating alternative capital rental price formulae in the context of MFP measurement. We first review the guidance provided by economic theory in discriminating amongst alternative rental price formulae employed in the empirical literature. This results in identifying a set of five possible rental price measures that we then evaluate in the context of a non-parametric, non-econometric MFP growth accounting framework. The empirical evaluation procedure is based on a comparison of the five alternative rental price estimates using a common data set covering twenty-one two-digit U.S. manufacturing industries over the 1948-81 time period, where each industry has from ten to twenty distinct types of capital assets.

The outline of the paper is as follows. In Section II we review the economic theory underlying productivity growth accounting, capital rental price measurement, and capital service flow aggregation. In Section III we motivate five alternative rental price formulations, each of which has an historical precedent in the investment, factor demand and/or productivity literature. In Section IV we discuss the data set underlying this study, motivate three quantitative measures we propose to employ in comparing the alternative rental prices, and then present empirical results. Finally, in Section V we summarize, present concluding remarks, and offer suggestions for further research.

2. THEORETICAL FOUNDATIONS

Since the purpose of this paper is to identify and evaluate the effects of plausible alternative capital service price measures on estimates of multifactor productivity (MFP) growth, in this Section we first briefly review the derivation of the MFP growth accounting equation, then summarize the derivation of rental price measures as estimates of the (usually) unobservable capital service prices, and finally discuss economic procedures for employing rental price estimates of capital service prices in aggregating capital services. This sets the stage in Section 3 for specifying the five alternative rental price estimates of capital service prices that span the range of possibilities suggested by economic theory and empirical practice in the investment and productivity liturature.

2.1 <u>Multifactor Productivity Growth Accounting</u>

Economic growth analysts have typically specified the multifactor productivity as,

$$MFP \equiv Y/X \tag{1}$$

where Y (X) is aggretate output (input). Assuming a single output, one can measure growth in aggregate input as the cost share-weighted aggregate of the growth in each of the inputs, so that (1) may be expressed in terms of growth rates as

$$M\dot{F}P = \dot{Y} - \Sigma \frac{P_i X_i}{C} \dot{X}_i, \tag{2}$$

where P_i is the price of input X_i, and C is total cost ($\equiv \Sigma P_i X_i$).

The multifactor productivity (MFP) growth accounting equation (2) may also be derived from the theory of cost and production. Assume that production

technology is described by a twice differentiable production function relating a single output to several inputs. Thus,

$$Y = F(X_1, \ldots, X_n, t). \tag{3}$$

The total differential of (3) with respect to time is

$$\frac{dY}{dt} = \Sigma \frac{\partial F}{\partial X_i} \frac{dX_i}{dt} + \frac{\partial F}{\partial t}. \tag{4}$$

Dividing both sides of (4) by Y, noting that,

$$\frac{dX_i}{Ydt} = \frac{X_i}{Y} \dot{X}_i, \text{ defining technical change as } \dot{A} \equiv \frac{1}{Y} \frac{\partial F}{\partial t}, \tag{5}$$

and rearranging we have

$$\dot{A} = \dot{Y} - \Sigma \frac{\partial/F}{\partial X_i} \frac{X_i}{Y} \dot{X}_i. \tag{6}$$

Comparing (6) with (2), we see that the condition necessary for technical change and MFP growth rate measures to be equivalent is that

$$\dot{X} = \Sigma \frac{P_i X_i}{C} \dot{X}_i.$$

Note that the first order conditions for cost minimization imply that,

$$\frac{\partial F}{\partial X_i} = \frac{P_i}{\partial C/\partial Y} \quad \text{where } \partial C/\partial Y \text{ is marginal cost,} \tag{7}$$

and that returns to scale of production may be measured as the reciprocal of the cost-output elasticity,

$$\epsilon_{CY} = \frac{\partial C}{\partial Y} \frac{Y}{C} \quad =) \quad \frac{\partial C}{\partial Y} = \epsilon_{CY} \frac{C}{Y}. \tag{8}$$

Substituting (7) and (8) into (6), and rearranging yields

$$\dot{A} = \dot{Y} - \Sigma \, \epsilon_{CY}^{-1} \, \frac{P_i X_i}{C} \, \dot{X}_i \quad . \tag{9}$$

Equations (2) and (9) are equal provided that production is characterized by constant returns to scale, i.e.,

$$\epsilon_{CY}^{-1} = 1.$$

In this case, technical change and MFP growth are equivalent, so that MFP growth may be calculated directly employing data on output growth, and on prices and quantities of inputs including, for example, prices and quantities of capital service inputs.[2]

2.2 Derivation of Capital Rental Price Formulae

Productivity analysts, at least since the work of Jorgenson-Griliches [1967], have noted that the aggregation of capital stocks is quite different from the aggregation of flows of capital services. Since the economic theory underlying multifactor productivity measurement is based on a production function relating flows of outputs to flows of inputs, the distinction between aggregation of capital stocks and the aggregation of capital service flows is an important one. On the dual side, it is correspondingly important to distinguish the purchase or asset prices of capital goods from their user costs or rental prices.[3]

While rental prices can be observed for some durable goods, in most cases rental market data is not sufficiently broad in coverage, and thus one must instead infer implicit rental prices based on the assumed correspondence between the purchase price of an asset and the discounted value of all future capital services derived from that asset.

There are a number of ways in which the rental price formula can be derived. Assume that as capital ages, physical deterioration and obsolescence cause it to depreciate relative to new goods, at the rate $\delta(\alpha)$, where α is the age of the asset. Denote the rental price of capital services at time t as p(t). Continuous time derivations relating p(t) to the asset price have been presented by, among others, Jorgenson [1967] and Hall [1968]. For example, with geometric deterioration, $\delta(\alpha) = \delta$, and the flow of capital services over the time interval dt beginning at t from a unit of capital goods acquired at time s is

$$e^{-\delta(t-s)}dt. \tag{10}$$

Since p(t) is the anticipated rental price of capital services at time t, then the expected discounted value of capital services is $e^{-rt}p(t)$, so that the value of the expected stream of capital services over the time interval dt is

$$e^{-rt}p(t) \cdot e^{-\delta(t-s)} dt. \tag{11}$$

Now let q(s) be the expected asset price of capital goods at time s. Then at time t = 0, the anticipated value of a unit of capital goods to be acquired at time s is,

$$e^{-rs}q(s). \tag{12}$$

In equilibrium, however, the expected value of capital goods acquired at time s must equal the expected discounted value of all future capital services derived from these capital goods, i.e.

$$e^{-rs}q(s) = \int_{s}^{\infty} e^{-rt}p(t) \cdot e^{-\delta(t-s)} dt = e^{\delta s} \int_{s}^{\infty} e^{-(r+\delta)t}p(t) dt. \tag{13}$$

Equation (13) can be solved for the expected asset price of capital goods, yielding

$$q(s) = \int_s^\infty e^{-(r+\delta)(t-s)} p(t) \, dt. \qquad (14)$$

Following Jorgenson [1967, p. 144], one can obtain the rental price of capital implicit in this equation by differentiating the expected asset value q(s) with respect to time:

$$\dot{q}(s) = [r(s) + \delta]q(s) - p(s) \qquad (15)$$

which can be rewritten as

$$p = q(r+\delta) - \dot{q}. \qquad (16)$$

Notice in particular that the rental price depends on the expected change in the asset price -- the expected capital gains term. This capital gains term will play a prominent role in the empirical analysis of this paper. It might also be noted that continuous time derivations of the rental price of capital which incorporate in addition expected corporate tax factors can be found in, among others, Hall-Jorgenson [1967].

A discrete time derivation for the rental price of capital is presented in Christensen-Jorgenson [1969]. The expected asset price is related to expected rental prices in discrete time form via the equality

$$q_t = \sum_{\tau=t}^{\infty} \prod_{s=t+1}^{\tau+1} \left(\frac{1}{1 + r_s}\right) p_{\tau+1} (1 - \delta)^{\tau-t} \, , \qquad (17)$$

where the quantity of capital services at time $\tau+1$ from one unit of investment in capital goods at time t is $(1-\delta)^{\tau-t}$. Christensen-Jorgenson rewrite (17) in the form

$$q_t = \left(\frac{1}{1 + r_{t+1}}\right) \cdot [p_{t+1} + (1-\delta)q_{t+1}], \qquad (18)$$

and then solve for the capital rental price, obtaining

$$p_t = r_t q_{t-1} + \delta q_t - (q_t - q_{t-1}). \tag{19}$$

Equation (19) may be interpreted as corresponding to the notional case where an asset purchased at the very end of the previous period (virtually the beginning of the current time period), the rental lease p_t is received at the end of the current time period, and the unknown but expected asset price at the end of the current time is $q^*_{t,t}$. Notice therefore that in the Christensen-Jorgenson discrete specification underlying (19), the capital revaluation term is

$$\text{expected capital gains} = q^*_{t,t} - q_{t-1}. \tag{20}$$

An alternative derivation of the discrete rental price of capital services is due to Diewert [1980, pp. 470-473]. Diewert assumes that capital is instantaneously adjustable and that during each time period firms lease all their capital goods at the rental price p(t) from a competitive leasing firm. The pressures of competition require that the leasing firm earn only the "prevailing" rate of return r(t) on its leasing activities. This implies the following equality at time period t:

$$(q_t - p_t)(1 + r_t) = (1 - \delta)q^*_{t,t+1} , \tag{21}$$

i.e. the purchase cost of one unit of capital q_t minus the rental p_t received, all multiplied by the opportunity cost of holding these funds $1 + r_t$, must equal the expected depreciated value of the capital good next period, this latter term being the product of the survival rate $(1-\delta)$ and the expected purchase price at time t for capital goods purchased in time period t+1, denoted $q^*_{t,t+1}$. When (22) is solved for p_t, one obtains

$$P_t = \frac{r_t q_t + \delta q^*_{t,t+1} - (q^*_{t,t+1} - q_t)}{1 + r_t}. \tag{22}$$

It should be emphasized that in (22), the expected capital gains term,

$$\text{expected capital gains} \equiv q^*_{t,t+1} - q_t, \tag{23}$$

plays a prominent role. Note from (22) that this expected capital gains term at time t is "forward looking", i.e. the rental price at time t depends on the expected asset price in period t+1. Finally, equations (21) and (22) can easily be modified to incorporate provisions of the tax code; see, for example, Diewert [1980, pp. 470-479].

It is informative to compare the Diewert and Christensen-Jorgenson discrete time formulae.[4] Rearranging (19) and lagging by one time period provides the Christensen-Jorgenson analog to (21):

$$q_{t-1}(1 + r_t) - p_t = (1 - \delta) q^*_{t,t}. \tag{24}$$

Equation (24) differs from (21) in several ways. While in Diewert's framework the opportunity cost of capital $(1 + r_t)$ multiplies the difference $(q_t - p_t)$, in the Christensen-Jorgenson specification $(1 + r_t)$ multiplies only q_{t-1}. Further, while the variables are identical (r, p and q), the time subscripts differ. In Diewert's formulation (21), the expected capital gains term affecting the rental price at time t is forward looking $(q_{t+1} - q_t)$, while in the Christensen-Jorgenson formulation (24) the capital gains term is retrospective, i.e., $q_t - q_{t-1}$ affects p_t. The difference stems, of course, from the discrete time choices made by Christensen-Jorgenson in specifying the time subscripts of (18) and (19).[5]

It is clear then, that while time subscripts differ, in both the Diewert and the Christensen-Jorgenson discrete time theoretical specifications, expected

capital gains play a very prominent role. An issue facing empirical

researchers, therefore, is how to measure the expected capital gains term. On

this, practice has varied among researchers and over time, due to the obvious

fact that theory provides little guidance, and that how expectations are formed

is to a major extent an empirical issue.

In Jorgenson [1963, 1965] and in Hall-Jorgenson [1967], the expected

capital gains term is set equal to zero since "...we assume all capital gains

are regarded as 'transitory'," (Jorgenson [1963, p. 249]). By contrast, in

Jorgenson-Siebert [1968a,b] two models are compared empirically, one

with perfectly anticipated capital gains where $q^*_{t,t} = q_t$ (this empirical

alternative is called Neoclassical I), and the other where expectations are

myopic and expected capital gains are zero, i.e. $q^*_{t,t} = q_{t-1}$ (this is called

Neoclassical II). Empirical results reported by Jorgenson-Siebert indicate a

modest preference for Neoclassical I (perfectly anticipated capital gains) over

Neoclassical II (no expected capital gains) in explaining the investment

behavior of fifteen firms. It is perhaps in part for this reason that since the

late 1960's, Jorgenson and his associates have only used Neoclassical I in their

empirical work on investment and productivity; see, for example, Jorgenson-

Griliches [1967], Fraumeni-Jorgenson [1980], Jorgenson-Sullivan [1981] and

Jorgenson-Fraumeni [1981].

At this point it is worth recalling that when Jorgenson-Griliches [1967]

originally introduced capital gains into the rental price calculations

underlying their MFP measures, they were sharply criticized by Edward Denison

[1969, p. 45], who argued that incorporating long-term averages of capital gains

"...might be appropriate", but that use of annual capital gains calculations was

dubious "...since capital gains are highly erratic from year to year."

Moreover, Denison noted that the relative capital gains of various types of

capital goods are of course unknown. This suggests that alternatives other than

the two neoclassical cases considered by Jorgenson-Siebert may merit empirical

examination; one obvious possibility is to employ as an estimate of $q_{t,t}^{*}$ a

moving average of previous asset prices, as has been done by Epstein [1977] and

Gillingham [1980]. We shall return to this point of alternative capital gains

specifications in the next Section.

What is clear from this brief review of the theoretical literature,

however, is that there are compelling reasons why the expected capital gains

term should be included in the rental price formulae; how these expectations

are measured and implemented empirically, however, is not as clear. Diewert

[1980, p. 476] summarizes this as follows:

> "...from our rather narrow viewpoint, which concentrates on
> the measurement of capital in the context of production function
> estimation and the measurement of total factor productivity, it
> seems clear that the capital gains term belongs in the rental price
> formula -- what is not as clear is the validity of the Jorgenson-
> Griliches perfect anticipations assumption."

The above discussion has focussed on the capital gains term in the rental

price formula. It is of course the case that other variables are also very

important, e.g. expected (marginal) tax terms, depreciation rates and the

discount rate or rate of return r. Diewert [1980, pp. 476-477] comments on this

as follows:

> "Which r should be used? If the firm is a net borrower, then r
> should be the marginal cost of borrowing an additional dollar for
> one period, while if the firm is a net lender, then r should be the
> one-period interest rate it receives on its last loan. In practice,
> r is taken to be either (a) an exogenous bond rate that may or may
> not apply to the firm under consideration, or (b) an internal rate
> of return. I tend to use the first alternative, while...Jorgenson
> and his co-workers use the second. As usual, neither alternative
> appears to be correct from a theoretical a priori point of view; so
> again, reasonable analysts could differ on which r to use in order
> to construct a capital aggregate."

A principal focus of this paper is to examine empirically not only these

two alternative measures of r, but also others that have appeared in the capital

rental price and capital aggregation literature. Before pursuing these alternative r measures, however, we briefly review the literature concerning the aggregation of capital services.

2.3 Capital Aggregation Theory and Procedures

In the next few paragraphs we provide a brief overview of procedures for aggregating over diverse capital services. Recall that since the analysis underlying MFP measurement is based on the economic theory of cost and production relating flows of inputs to flows of outputs, empirical implementation with durable goods requires obtaining measures of the aggregate flows of capital services, not aggregate stocks. Although it is relatively straightforward to obtain measures of the one-period value of capital services, it is more difficult to decompose this value into price and quantity components. In the previous paragraphs we have outlined how rental prices can be formed for different capital assets; details concerning tax factors affecting these rental prices will be discussed later.

With respect to quantities of service flows, we follow tradition here and make the assumption that capital services for each type of asset (e.g., producers' durable equipment, non-residential structures, inventories and land) are a constant proportion of capital stocks; this factor of proportionality can however vary among the diverse types of capital assets. In order to estimate service flows for each asset type, it is therefore only necessary to develop corresponding capital stock estimates. We employ the perpetual inventory method (PIM) to perform vintage aggregation for each asset. When deterioration is geometric, the PIM for capital type i is

$$K_{i,t} = (1 - \delta_i)K_{i,t-1} + I_{i,t-1} \qquad (25)$$

where δ_i is the rate of deterioration for capital type i, $K_{i,t}$ is the beginning-of-year constant dollar capital stock, and $I_{i,t-1}$ is constant dollar gross investment in capital type i during time period t-1 that is assumed to be installed by the beginning of time period t. Repeated substitution into (25) yields an expression relating $K_{i,t}$ to the history of vintage-specific gross investments, each weighted by their relative efficiency. When deterioration patterns other than geometric are employed, the $1 - \delta_i$ factor for each vintage reflects the assumed deterioration pattern of the asset based on a fixed schedule of remaining efficiency as a function of age. Notice that the PIM is applied separately to each of the various capital assets.

Once these rental price and capital service quantity flows are separately measured, they must be aggregated. Here we assume that capital is instantaneously adjustable and employ the familiar Tornqvist discrete approximation to the continuous Divisia index. The Tornqvist approximation to the Divisia index has attractive properties, for as has been shown by Diewert [1976], it can be viewed as an exact index corresponding to a second order approximation in logarithms to an arbitrary production or cost function.[6] In particular, this index places no prior restrictions on the substitution elasticities among the goods being aggregated. With the Tornqvist approximation, the change in aggregate capital service flow is a weighted sum of the changes in the n asset-specific capital stocks, where the weights are the relative cost shares:

$$\ln (K_t/K_{t-1}) = \sum_{i=1}^{n} \bar{s}_{i,t} \ln (K_{i,t}/K_{i,t-1}) \tag{26}$$

where
$$\bar{s}_{i,t} \equiv (s_{i,t} + s_{i,t-1}) / 2$$

$$s_{i,t} \equiv p_{i,t} K_{i,t} / (P_{K,t} K_t)$$

and where the aggregate value of capital services $P_{K,t} K_t$ equals the sum over

all n asset values,

$$P_{K,t} K_t = \sum_{i=1}^{n} p_{i,t} K_{i,t} , \qquad (27)$$

where i refers to the ith type of capital asset, and p_i is its rental price.[7] Equations (26) and (27) demonstrate the important role of the rental price in capital service aggregation, and in decomposing the aggregated value of capital service flows into price and quantity components.

This Divisia aggregation of capital services weights each type of capital by its relative cost share, and should be distinguished from the direct summation or aggregation of capital,

$$\tilde{K}_t = \sum_{i=1}^{n} K_{i,t}. \qquad (28)$$

An important feature of aggregate capital growth, emphasized by Jorgenson-Griliches [1967], is that Divisia aggregation (26) can generate very different growth rate results than the direct aggregation (28). For example, suppose that the composition of capital changes because greater investment is occurring for shorter-lived equipment than for longer-lived structures. As a result, since δ_e for equipment is larger than δ_s for structures (equipment has a shorter life span and thus a larger deterioration rate), from (16), (18) and (22) it is clear that, _ceteris paribus_, the rental price of equipment p_e will be larger than the rental price of structures p_s. This implies that the growth of equipment investment will be weighted more highly than growth in structures in the Divisia aggregation (26), and aggregate capital computed using this Divisia index will grow at a larger rate than aggregate capital calculated using direct aggregation (28). The economic intuition underlying this is that because of the shorter life of equipment, the investor needs to require more services per year from a given dollar of investment in equipment than in structures, i.e. a dollar's

worth of investment in equipment has higher "quality" (in terms of service flow per dollar) than a dollar's worth of investment in structures.

The empirical importance of employing correct capital aggregation procedures may be illustrated using data for the U.S. Private Business Sector. We denote the difference between the growth rates of the rental price-weighted Divisia index and a directly aggregated capital stock as the capital composition effect. In the post World War II U.S. economy, this effect has been strongly positive, due to the steady shift in the investment mix toward shorter lived equipment assets and away from structures and land.

As is seen in Table 1, for the 1948-84 time period in the U. S. Private Business Sector, capital input (using the Divisia aggregation) grew 3.4% per year, while capital stock (using direct aggregation) grew only 2.6% per year; this implies a 0.8% capital composition effect. One underlying reason for this is that equipment grew 4.9% per year while nonresidential structures grew 2.8%,

(TABLE 1 SOMEWHERE NEAR HERE)

inventories grew at 3.3% and land at only 2.0%. The resulting MFP measure increased at a 1.5% rate; had the unweighted direct aggregation been employed to aggregate capital stock instead of capital services, the measured MFP growth would have grown at 1.8% per year. Average capital productivity (growth in output minus growth in capital input) is 0.0% using Divisia aggregation, and is 0.8% if defined instead in terms of growth in output per unit of capital stock. The long-run constancy of the capital-output ratio, incidentally, is consistent with an economy experiencing long-run balanced growth, and is an empirical finding that would be overlooked were the rental price approach to capital measurement not employed. Finally, note that the importance of the capital composition effect has declined considerably over time; from 1948-73 it

averaged 0.9% per year, while from 1973-1981 it fell slightly to 0.6% per year, and over the most recent 1981-1984 time period it dropped to 0.2% per year.

This concludes our discussion of the theory and interpretation of rental price formulae, as well as their role in the aggregation of capital services. An important conclusion of the above discussion is that while capital gains and rates of return should enter into the calculation of capital rental prices, economic theory alone cannot tell us how they should be measured empirically. In the next section, therefore, we outline five alternative rental price measurement procedures, and then in Section IV we compare them empirically using a common data set.

3. ALTERNATIVE SPECIFICATIONS OF THE RENTAL PRICE MODEL

Earlier it was noted that the capital rental price formulae can easily be modified to incorporate effects of corporate tax provisions in the U.S. For example, the Christensen-Jorgenson formula (22) for the ith capital asset type now becomes

$$p_{i,t} = T_{i,t}(q_{i,t-1}r_t + \delta_{i,t}q_{i,t} - (q^*_{i,t} - q_{i,t-1})) + b_{i,t} \tag{29}$$

where $b_{i,t}$ is the effective rate of property taxes (nominal valued taxes assessed on the real stock of capital type i), and $T_{i,t}$ is the effective rate of taxation on capital income given by

$$T_{i,t} \equiv \frac{1 - u_t z_{i,t} - k_{i,t}}{1 - u_t}, \tag{30}$$

where u_t is the maximum statutory corporate income tax rate[8], $z_{i,t}$ is the present value of depreciation deductions for tax purposes on a dollar's investment in capital type i over the lifetime of the investment, and $k_{i,t}$ is the effective rate of the investment tax credit. Note that each of the

variables in (29) and (30) is estimated for different asset type categories,
thereby generating distinct estimates of the rental prices of the various
capital types.

BLS researchers have implemented estimation of (29) and (30) for various
asset types and sectors of the economy; such calculations underlie the figures
presented in Table 1 above. In almost all cases, procedures developed by
Christensen-Jorgenson [1969], as modified slightly in Fraumeni-Jorgenson [1980],
have been followed. In particular, the $q_{i,t}$ are capital asset-specific
investment goods deflators, while the $\delta_{i,t}$ are inferred from the assumed
deterioration function by making use of the duality between the service flow and
price of an asset as it ages. This relationship has been derived by Hall [1968]
in continuous time terms, and by Jorgenson [1974] in discrete time. Discussion
of the tax variable computations is found in Christensen-Jorgenson [1969] and in
Harper [1982].

As was noted in the previous section, empirical practice has varied
concerning choice of the rate of return r_t and the specification of capital
gains $(q^*_{it,t} - q_{i,t})$. We now discuss five alternative empirical implementations
of (29), comment briefly on their salient empirical features, and then in the
next section we compare them empirically in more detail.

3.1 Internal Nominal Rate of Return Specification

We begin with the internal nominal rate of return specification, developed
in detail by Christensen-Jorgenson [1969], discussed in further detail by
Fraumeni-Jorgenson [1980], and employed by the BLS [1983]. Define property
income in year t as I_t ($\equiv P_{K,t}K_t$), where I_t consists of pre-tax profits, capital
consumption allowances, net interest, transfer payments, business subsidies,
indirect taxes, and the portion of proprietor's income attributable to capital,
all taken from the National Income and Product Accounts. Assuming that the rate

of return is the same for all assets, one can solve for the internal nominal
rate of return r_n as

$$r_{n,t} = [I_t + \sum_{i=1}^{n} (-\delta_{i,t} T_{i,t} q_{i,t} K_{i,t} + \Delta q_{i,t} T_{i,t} K_{i,t} - b_{i,t} K_{i,t})] \tag{31}$$

$$/ \sum_{i=1}^{n} q_{i,t-1} T_{i,t} K_{i,t}$$

where I is property income as defined above and $\Delta q_{i,t} = q^*_{i,t} - q_{i,t-1}$. Note
that with this internal nominal rate of return procedure the aggregate capital
gains term $\Sigma \Delta q_{i,t} T_{i,t} K_{i,t}$ enters with a positive sign so as to augment capital
income reported in the National Income and Product Accounts, and thereby
increases r. However, as seen in (29), asset-specific inflation reduces p_i.
This suggests that when asset-specific inflation coincides with the aggregate
rate of capital inflation, p_i calculated using (31) will be unaffected; we
discuss the importance of non-neutral inflation further in the next subsection.
It is also important to recognize that when the internal nominal rate of return
procedure (31) is employed, expected capital gains are replaced with realized
capital gains, which implies that in this procedure capital gains are assumed to
be perfectly anticipated.

We refer to this rate of return as an after-tax "nominal internal" rate
because it is derived in terms of property income for the specific industry
(thereby, internal) and because it includes perfectly anticipated capital gains
(hence, nominal).[9] This procedure corresponds with what Jorgenson-Siebert
[1968a,b] have called their "Neoclassical I" model. Hereafter we denote the
rental prices of capital for the ith capital type based on this internal nominal
rate of return $p_{i,n}$.

We now examine movement in $p_{i,n}$ and its components empirically. It will be
useful to divide the rental price (29) into four components: (i) rate of

return, $T_{i,t}q_{i,t-1}r_t$; (ii) depreciation, $T_{i,t}\delta_{i,t}q_{i,t}$; (iii) capital gains,
$T_{i,t}\Delta q_{i,t}$; and (iv) indirect taxes, $b_{i,t}$. A striking feature of the $p_{i,n}$ time
series we have observed is its volatility; note that volatility in $p_{i,n}$
generally results in comparable volatility in the cost share weights used to
aggregate capital (see (26)). We illustrate this feature in Table 2 with the
metal working machinery asset in the miscellaneous manufacturing industries
sector, SIC 39. The data underlying these results are described in Section
IV.A. Shown for the period 1971-1981 are the shares of this asset in this
industry's total capital income (equation (27)), the rental price $p_{i,n}$ based on
the internal nominal rate of return (equations (29) and (30)), the four
components of the rental price listed above, and finally, the internal nominal
rate of return derived for this industry (see (31)).

(TABLE 2 SOMEWHERE NEAR HERE)

Empirical results for this asset and this industry are representative of
those obtained for other assets and industries with $p_{i,n}$. Substantial
fluctuations occur for the income share, with particularly large drops
experienced in 1975 and 1981. The rental price shows similar sharp decreases,
moderated to some extent by the strong inflationary trend. The depreciation
component increases steadily, buoyed by inflation; steady increases also occur
for the indirect tax component.

An examination of the rate of return and capital gains components reveals
that these two terms are the source of most of the fluctuations around trend in
$p_{i,n}$; note that standard deviations for the rate of return and capital gains
components are substantially larger (especially relative to their means) than
those for the depreciation and property tax components. For example, in 1975
the sharp drop in rental price can be linked to a substantial increase in

capital gains, indicating that the investment goods deflator for this asset advanced rapidly between 1974 and 1975. By contrast, in 1981 the drop in rental price occurs primarily due to the sharp drop in the rate of return; this decrease in the nominal internal rate of return was in turn due in large part to the decreased rate of inflation for all other asset types, which enters of course into the r_n calculation (31). Note that capital gains for this particular asset increase considerably (in absolute value) from 1976-1980, but these asset-specific capital gains are roughly offset by increased contributions from the rate of return term, contributions which in turn are influenced by the general inflation in capital asset prices.[10]

3.2 Internal Own Rate of Return Specification

The second alternative rental price specification we consider is very closely related to the "Neoclassical II" model examined by Jorgenson-Siebert [1968a,b]; interestingly, this alternative is also discussed by Jorgenson-Griliches [1967, p. 256, fn. 2], who attribute it to an earlier paper by Domar [1961]. This specification, which we call the internal own rate of return, seems to exclude capital gains from the rental price formula and therefore apparently incorporates the assumption of zero expected capital gains, or myopic expectations. If this were true, then this alternative would be subject to Jorgenson and Diewert's theoretical criticism that capital gains should be included in the rental price formula. As we shall see, however, this is not quite the case.

Suppose we exclude the capital gains term from (20),

$$p_{i,o} = T_{i,t}(q_{i,t-1}r_{o,t} + \delta_{i,t}q_{i,t}) + b_{i,t} \tag{32}$$

and, correspondingly, simultaneously solve for an "own" rate of return, denoted r_o, which excludes from (31) the aggregate capital gains term $\Sigma T_i \delta q_i K_i$, as

$$r_{o,t} \equiv [I_t - \sum_{i=1}^{n} (\delta_{i,t} T_{i,t} q_{i,t} K_{i,t} + b_{i,t} K_{i,t})] / \sum_{i=1}^{n} q_{i,t-1} K_{i,t} T_{i,t} \qquad (33)$$

We denote the rental price measure based on r_o, the internal own rate of return, as $p_{i,o}$, and equations (32) and (33) as the "internal own rate of return" model.

When this alternative set of computations is performed with our same sample data for the metalworking machinery asset in SIC 39, we find that fluctuations (as measured by the standard deviation) in the rate of return contribution and in the income share are greatly reduced. This is demonstrated in Table 3. One other interesting feature of this table is that while r_o has only one third as large a standard deviation as r_n from Table 2, due to the very large rental price $p_{i,o}$ in 1981 in Table 3, the standard deviations of the rental prices $p_{i,n}$ and $p_{i,o}$ are approximately equal.

{ TABLE 3 SOMEWHERE NEAR HERE }

The above discussion would seem to suggest that this internal own rate of return model suffers from Jorgenson and Diewert's theoretical criticism that capital gains should be included in the rental price formula. We now demonstrate that this is not the case. A comparison of (31) and (33) reveals that the internal nominal and internal own rate of return notions are related as follows:

$$r_{n,t} = r_{o,t} + (\sum_{i=1}^{n} \Delta q_{i,t} T_{i,t} K_{i,t} / \sum_{i=1}^{n} q_{i,t-1} T_{i,t} K_{i,t} \qquad (34)$$

$$= r_{o,t} + (\Delta \bar{q}_t / \bar{q}_{t-1}) = r_{o,t} + \text{average capital gains,}$$

where

$$\Delta \bar{q}_t \equiv \sum_{i=1}^{n} \Delta q_{i,t} T_{i,t} K_{i,t} \qquad \text{and} \qquad \bar{q}_{t-1} \equiv \sum_{i=1}^{n} q_{i,t-1} T_{i,t} K_{i,t}. \qquad (35)$$

Incidentally, Fraumeni and Jorgenson [1980] have defined the difference between r_n and average capital gains (see (34)) as the "own rate of return".

Let us define a new rental price formula where average rather than own capital gains appear, and denote this rental price with average capital gains as $p_{i,a}$:

$$p_{i,a} = T_{i,t}[q_{i,t-1}r_{a,t} + \delta_{i,t}q_{i,t} - q_{i,t-1}(\Delta\bar{q}_t/\bar{q}_{t-1})] + b_{i,t} \qquad (36)$$

where $r_{a,t}$ is calculated as

$$r_{a,t} \equiv [I_t + \sum_{i=1}^{n}(-\delta_{i,t}T_{i,t}q_{i,t}K_{i,t} + q_{i,t-1}(\Delta q/\bar{q}_{t-1})T_{i,t}K_{i,t} - b_{i,t}K_{i,t})]$$

$$/ \sum_{i=1}^{n} q_{i,t-1}K_{i,t}T_{i,t} \qquad (37)$$

$$= \{[I_t - \sum_{i=1}^{n}(\delta_{i,t}T_{i,t}q_{i,t}K_{i,t} + b_{i,t}K_{i,t})]$$

$$/ \sum_{i=1}^{n} q_{i,t-1}K_{i,t}T_{i,t}\} + (\Delta\bar{q}_t/\bar{q}_{t-1}) \quad .$$

By substituting into (33), the second part of (37) can be rewritten as

$$r_{a,t} = r_{o,t} + \Delta\bar{q}_t/\bar{q}_{t-1} \qquad (38)$$

Now if (38) is substituted into (36), the average capital gains terms weighted by $q_{i,t-1}$ cancel out, and, comparing the result with (32), yields $p_{i,a} = p_{i,o}$. This implies the following very important result:

Use of the internal own rate of return model (with apparently no capital gains) yields the same rental prices and thus cost shares as would the nominal internal rate of return model provided average capital gains were employed in the nominal rental price equations (29) and (31) instead of the asset-specific capital gains rates.

Hence, the internal own rate of return model preserves the important theoretical requirement that some account of capital gains be made in the rental price expression.

One other result is worth emphasizing. Together (34) and (38) imply that $r_a = r_n$, i.e. aggregate internal rates of return based on nominal asset-specific and average capital gains are equal. However, for specific assets, $p_{i,o}$ ($= p_{i,a}$) differs from $p_{i,n}$ by the difference between the average and asset-specific capital gains rates. Hence instability of rental prices $p_{i,n}$ relative to $p_{i,o}$ can be attributed to unequal movements in <u>relative</u> asset prices.

3.3 Internal Nominal Rate of Return with Smoothed Capital Gains

Earlier we noted that in his survey of capital aggregation, Diewert [1980] suggested that researchers may wish to follow the lead of Epstein [1977] and use time series techniques to obtain asset-specific expected capital gains measures; such a "smoothed" capital gain term could provide a useful alternative to the polar assumptions of zero and perfectly anticipated capital gains.

The issue of asset-specific capital gains was raised earlier by Denison [1969], who in his discussion of the Jorgenson-Griliches [1967] productivity analysis provided a numerical example in which asset-specific price changes affected both cost share weights and the measure of aggregate capital, albeit in a moderate manner. Denison conceded that asset-specific price changes should theoretically affect firms' decisions, yet also noted that firms do not know in advance how relative prices will move, and thus the empirical researcher must attempt to model the relative price expectations process.

As we demonstrated above, it is only the relative movements in asset prices that affect rental prices and aggregation. While a full econometric model of price determination and price expectations may be desirable in this context, a much simpler procedure would be to employ time series or ARIMA techniques in

measuring _ex ante_ relative price expectations, where relative price is defined as the ratio of each asset's price to the overall average of all investment goods prices.

Such a moving average of previous relative asset prices has been employed by Gillingham [1980], in conjunction with his study of restructuring the BLS Consumer Price Index housing component. After finding an "unacceptable" amount of volatility emerging from the traditionally computed capital gains term (sometimes resulting even in negative rental prices), Gillingham experimented with using moving averages of from two to five years, reasoning that in forming their expectations firms and individuals may examine recent trends particularly closely. Unfortunately, Gillingham found that whether the moving average notion was applied only to capital gains, only to the rate of return, or to both, the result was still the same in that very large variations still occurred. This led Gillingham to suggest that for this component of the CPI it would be preferable to use market rental prices of equivalent rental housing rather than rental prices computed using the above methods.

In this paper, we propose to examine empirically the behavior of a special case of the ARIMA model, namely, a three-year moving average with equal weights applied to each lag. We therefore measure both capital gains and rates of return with the three year moving average replacing $\Delta q_{i,t}$ in (29) and (31).

3.4 External Nominal Rate of Return Specification

A number of studies of investment behavior and costs of capital have employed as a measure of the expected or _ex ante_ discount rate some bond yield in external markets. The most common are Moody rates for Aaa or Baa rated bonds, or long-term U.S. government bond yields. Aaa yields, for example, have been employed by Coen [1968], Evans [1967], Grunfeld [1960] and Miller-Modigliani [1966], while Baa yields were used by Holland and Myers [1979];

Eisner [1969] reports results of experiments with the U.S. government long term

bond rate as reported in the Survey of Current Business.

As an empirical alternative, therefore, we replace r_n in (29) with r_b,

where r_b is the Moody Baa bond rate; given the implied rental prices $p_{i,b}$, we

recompute costs of capital for each asset as $p_{i,b}K_i$, and then use (27) to obtain

new cost shares. Note that if this measure is used as an ex ante measure of the

cost of capital, unrealized expectations could result in a divergence between ex

ante and ex post capital costs. As a measure of the implied "surprise", we take

the ratio of actual income to the implied ex ante capital income, $I/(\Sigma p_{ib}K_i)$.

This ratio can also be interpreted as the adjustment necessary to use the $p_{i,b}$

to apportion actual current income. To see this, note that the above ratio is a

stock-weighted average of the ratio of ex post rental prices to ex ante rental

prices, due to the relationship (31) between income and the ex post internal

rate of return. We refer to this specification as the external nominal rate of

return model.

Using the same asset category and industry as in Tables 2 and 3, in Table 4

we present results based on rental price and rate of return calculations with

r_b. The additional final column in Table 4 is the "surprise" ratio defined in

{ TABLE 4 SOMEWHERE NEAR HERE }

the previous paragraph. Note that this ratio is very large, varying from —2.47

to 6.34, implying considerable magnitude in the "surprise" element. Moreover,

for some years capital income is computed as being negative, since a negative

rental price results from using r_b. It is also worth noting, incidentally, that

the results in Table 4 are representative of employing the r_b method for other

assets and industries.

3.5 Constant External Own Rate

When property income becomes negative, none of the above four methods is capable of generating reasonable capital rental prices. In particular, the implied shadow price of capital is in such cases negative, implying that the firm could reduce variable costs by discarding its capital plant and equipment. While such a situation may be possible in theory, one would not expect to observe this in practice, for firms do have the option of shutting down in the short run if revenues do not cover variable costs. On the other hand, one could argue that if one obtained negative capital income measures, that would indicate problems with the data or the measurement method employed. We shall discuss negative capital income issues further in the next section.

One way of obtaining "reasonable" rental price measures in such cases is to remove from the underlying calculations the elements causing the large fluctuations. As has been pointed out earlier, these elements in most cases are the capital gains term and the linking of the rate of return to capital or property income. Possibilities here include employing a before-tax constant nominal rate of return, such as 14% (Hall-Jorgenson [1968], 20% (Hall-Jorgenson [1969]), or 10% (Coen [1975]). More recently, Fraumeni-Jorgenson [1980] have calculated that the difference between nominal discount rates and inflation rates appears to be approximately 3% - 4% for most industries.

This suggests our final empirical alternative, namely, a model in which the the real rate of return (r_n minus capital gains) is set to a constant 3.5%; we denote this as r_c. In this alternative we therefore substitute r_c for r_o in (32), calculate the corresponding $p_{i,o}$ (which are now always strictly positive), compute the capital costs as $p_{i,o}K_i$, and then calculate shares using (27). It is worth noting, incidentally, that this 3.5% constant real rate of return has been employed by the BLS [1983] in its MFP calculations for the agriculture

sector, a sector in which traditional property income measures occasionally become negative.

3.6 Summary

We propose to compare and evaluate the five alternative capital rental price formulae discussed in sections 3.1-3.5. The sources and characteristics of these formulae are summarized in Table 5. The important features include:

(i)   all five capital rental price estimates reflect capital appreciation, and so are consistent with the theoretical conditions of Jorgenson and Diewert.

(ii)   formulae M1, M2, & M4 ensure that NIPA capital income estimates equal the "payments" to specific assets, while formulae M3 & M5 do not impose this constraint. Hence in calculating MFP growth (see equation (9)), M1, M2 & M4 leave the aggregate capital share unaffected and differ only in their estimate of aggregate capital service growth rates due to differences in specific asset rental value shares. For M3 and M5, both rental cost shares and service flow growth rates are affected.

(iii)   formulae M1 and M2 are closely related, differing only in the contribution of non-neutral changes in relative asset prices to average capital appreciation.

It should be recalled that the M1-M5 formulae are all motivated either by conceptual arguments or their use in the literature. Given the assumptions underlying the multifactor productivity growth equation (9), however, we prefer the standard internal nominal rate of return (M1), the internal own rate of return (M2), and the internal nominal rate of return with smoothed capital gains (M4) models. Theoretical arguments cannot discriminate further amongst these formulae, and so final choices must depend on empirical evaluation.[11]

(TABLE 5 SOMEWHERE NEAR HERE)

4.   EMPIRICAL RESULTS

We now turn to a comparative evaluation of the five capital rental price formualae described above. At the outset, it is useful to note that there are two possible outcomes from such comparisons. First, perhaps there is not much empirical difference among the various measures, or at least among the measures for the preferred rental price estimates (M1, M2 & M4). This would be good news for productivity growth analysts since then they would not need to be too concerned about the lack of theoretical help in choosing a specific rental price formula -- at least for U.S. manufacturing industries. Alternatively, of course, there may be considerable empirical variation in the estimated rental price formulae, leaving productivity growth analysts with the difficult task of choosing and justifying a particular formula.

The comparative quantitative measures we employ to evaluate the effects of alternative rental price specifications focus on (i) the overall capital measure, (ii) the variability of the rental prices, and (iii) the consistency of the measures with the requirements of basic economic theory. Recall from equation (9) that the capital rental prices influence MFP growth estimates via affects on (i) the aggregate capital service flows as estimated by equation (26) -- a quantity effect, and (ii) on the value of aggregate captial services calculated by identity (27) -- a price effect. We evaluate the quantity effect by calculating the ratio of the price weighted aggregate capital service flow to the unweighted, or physical, aggregate capital service flow from equation (28). As noted in section 2.3, we call this measure the capital composition effect.

The price effect may be evaluated by focussing on the variability of the asset rental prices. As noted, aggregate rental prices may be computed using Tornquist-Divisia indexes of capital service flows (26) and the capital income identity (27). By inspection of (26) and (27), it is seen that asset rental price variability contributes to variability of aggregate service prices

directly, and indirectly via the relative size of the asset value shares used in capital service aggregation. We focus on the net effect of component rental price variability by calculating as our second comparative measure the year-to-year percentage changes in absolute values of aggregate rental service price estimates, a measure we call the volatility statistic.[12]

Finally, recall that the assumptions underlying the derivation of the multifactor productivity growth equation (9) require that input flow prices be positive. Nothing in the procedures for calculating any of the five capital rental prices considered in this study imposes the restriction that the resulting estimates are positive. Accordingly, we tabulate first by industry, and then for total U.S. manufacturing, the number of negative outcomes, expressing the result as a percentage of the total observations for all assets and years. We call this characteristic the percentage negative statistic.

Table 6 presents values of the composition effect, and the volatility and percent negative statistics for each of the twenty-one two-digit U.S. manufacturing industries over the 1948-81 time period. Several results should

(TABLE 6 SOMEWHERE NEAR HERE)

be noted. First, composition effects and especially the volatility statistics are very large and questionable for the external nominal rate of return model (M5). This suggests that the problem illustrated in Table 4 concerning the large required reallocation of property income due to differences between ex post and ex ante incomes is significant in the industries considered in this study. The relatively large percentage of negative rental prices and the general breakdown of other statistics stems from the fact that the ex post capital gains term frequently dominates the ex ante rate of return as measured

by the Moody Baa bond yield. Because of these adverse results, we exclude the external nominal rate of return model (M5) yield from further analysis.

Second, notice that for three of the remaining four rental price alternatives (M1, M2, M3), the composition effect is extremely large for NIPA 16 (transportation equipment excluding automobiles). This occurs because in these internal rate of return calculations, property income occasionally becomes negative, especially in 1980 and 1981. Note also that for this same industry, the percent negative values are higher than for any other industry. The other industry with atypical statistics is NIPA 15 (automobile motor vehicles), closely related to NIPA 16. The atypical behavior of these two sectors suggests that they be eliminated from further consideration until questions about the underlying data can be resolved.

In Table 7, we present simple averages of the composition, volatility and percent negative statistics for nineteen of the twenty-one two digit industries (excluding NIPA 15 and 16), separately for the 1948-65, 1966-73 and 1974-81 time periods, for the four remaining rental price specifications (M1-M4). Several points should be noted.

{ TABLE 7 SOMEWHERE NEAR HERE }

First, a striking result from Table 7 is that the ranking of the four alternatives is essentially the same for all three measures, with M1 and M4 having the two highest values, then M2, and finally M3. This relative ranking holds for all sub-periods, with the absolute differences among the four alternatives being largest during the relatively turbulent 1974-81 time period. This average ranking pattern is also approximately the same for individual industries, as can be seen from Table 6.

Second, the composition effect (the ratio of economic and physcial aggregate capital services) is positive and largest for the two internal nominal alternatives (M1, M4 of Table 7), is positive but much smaller for the internal own (M2), and is slightly negative for the external own (M3). Moreover, while the entries in the composition effect panel of Table 7 might appear small, in fact the differences among the four alternatives are substantial, especially for the 1974-81 time period when they range from -0.037 to 0.315; such magnitudes are as large as some of the other major factors typically examined in studies of the sources of the post-1973 productivity growth slowdown, and clearly indicate that measurement procedures do matter.

Third, the capital composition effect reflects a systematic trend in the relative prices of the different asset types. Recall that for the two nominal internal models (M1, M4), asset-specific capital gains are incorporated, while with the internal own (M2) and external own (M3) they are omitted. Significantly, M1 and M4 have the largest capital composition effects, while M2 and M3 have much smaller composition statistics. This result is due to (i) the long term historical shift towards equipment and away from structures (which directly increases the capital composition effect), and (ii) the long-term tendency for the prices of new structures to rise more rapidly than those for equipment, causing the capital gains term subtracted in the structures rental price to be larger than that subtracted in the equipment rental price. This latter effect accentuates the existing difference between equipment and structures rental prices occurring due to the higher economic depreciation of equipment, and thereby results in a larger rental price and cost share weight for the more rapidly growing equipment services component. The more investors take these differential asset-specific capital gains into consideration, therefore, the larger should be the composition effect.

Fourth, the standard internal nominal rate of return specification (M1) yields the largest percent of negative rental prices; for the 1948-73 time period, this percent negative is rather small at 0.5-0.6%, increasing to 3.9% in the 1974-81 period. By comparison, the percent negative figures for M4 for the 1974-81 period is 2.3%, and for M2, 1.0%. For M3, the percent negative is of course zero for all time periods. What the bottom horizontal panel of Table 7 suggests, therefore, is that most of the negative rental price occurrences correspond with the use of asset-specific capital gains (the largest percent negative values are with internal nominal and internal nominal smoothed); when average capital gains or no capital gains at all are employed (M2, M3), the percent negative occurrences for the rental price fall sharply.

While direct inspection of Tables 6 and 7 is instructive, we are still left with the question, how statistically significant are differences among alternative rental price formulae in explaining variations in the three characteristics -- composition, volatility and percent negative? To address that question, we have analyzed each of the three characteristics using regressions models in which the dependent variables are the composition effect, the volatility statistic, and the percent negative. In one case the right-hand variables are dummy variables for M2, M3, and M4, and time dummy variables for the 1966-73 and 1974-81 time periods. In the second case, we include interaction terms between each model and each dummy time period defined as $M(I) * D(K)$ ($I = 2,3,4$, and $K = 1966-73$, 1974-81). For both models, the constant term is therefore interpreted as the mean difference from the standard internal nominal rate of return model (M1) for the 1948-1965 time period. These six regressions are run using the data set consisting of the nineteen industries, four models and three time periods, yielding a total of 228 observations. Results from this set of regressions are presented in Table 8.

(TABLE 8 SOMEWHERE NEAR HERE)

We begin with a discussion of the composition effect. As shown in the

first column of Table 8, of the model dummy variables only the M4 (constant

external own at 3.5%) coefficient is statistically significant, and it is

negative, indicating a statistically significant smaller composition effect with

the M4 model than with the standard M1 specification (internal nominal own).

Since each of the 1966-73 and 1974-81 time dummies is positive and statistically

significant, we conclude that for all models the composition effect is larger in

the more recent time periods than in 1948-65. Inspection of column (ii) of the

composition effect indicates that, as judged by their implied t-statistics, at

most one of the interaction terms (M4 - 1974-81) is statistically significant

(and this is marginal). A joint test of the null hypothesis that simultaneously

all interaction term coefficients are zero cannot be rejected; the F-test

statistic is 1.51, while the .95 (.99) critical value is 2.10 (2.80).

The second set of regressions reported in Table 8 employ the volatility

characteristic statistic as the dependent variable. As seen in the middle two

columns of Table 8, each of the model coefficients is statistically significant

(and negative). In the specification with no interactions, this indicates that

the volatility of the M1 base case (internal nominal rate of return) model is

statistically significantly larger than that of the other three models, while in

the interaction specification this statistically significant difference holds in

both the 1948-65 base case, and even more so in the 1974-81 time period. The

coefficient of .216 coefficient for the 1974-81 time dummy in the interaction

specification implies that for the standard internal nominal own rate of return

model (M1), volatility is statistically significantly larger in the turbulent

1974-81 time period than in 1948-65. Here a joint test of the null hypothesis

that all interaction terms in the volatility equation are simultaneously equal

to zero is rejected; the F-test statistic is 2.99, while the .05 (.01) critical value is 2.10 (2.80).

Regression results for the "percent negative" measures are presented in the final two columns of Table 8. In the model with no interactions, as implied by their t-statistics, the M2 (internal own) and M3 (external own) model coefficients are negative and statistically significant, while the 1974-81 time period coefficient is positive and statistically significant. This leads us to conclude that while the M1 base case (internal nominal own rate of return) model has a statistically significantly more occurrences of negative rental prices than both the M2 (internal own) and M3 (external own 3.5%) models in the 1948-65 time period, this difference is increased further during the 1974-81 epoch; differences between the M2 and M3 models are, however, statistically insignificant.   These conclusions are amended slightly when one examines the interaction model. Now the model-specific coefficients are negative and statistically significant primarily only in the 1974-81 time period, suggesting that during this time span the M1 base case (internal nominal own rate of return) model experienced significantly more occurrences of negative rental prices. Finally, the test of the null hypothesis that all six interaction term coefficients are simultaneously equal to zero is again rejected; the F-test statistic is 3.56, while the .05 (.01) critical value is 2.10 (2.80).

5.   SUMMARY AND CONCLUDING REMARKS

The U.S. Bureau of Labor Statistics has recently begun to estimate and publish measures of multifactor productivity (BLS [1983]). An important issue in constructing these estimates is the measurement of (typically) unobservable capital service prices. In this paper, we (i) review the economic theory underlying the derivation of rental price estimates of unobservable capital service prices; (ii) formulate five alternative rental price formulae based on economic theory and on previous empirical applications in the economic literature; and (iii) empirically analyze these five alternatives.

The review of the underlying theory and the motivation of the five alternative captial rental price formula emphasizes the importance of incorporating information on economic depreciation, expected rate of return, expected tax rates, and expected capital asset appreciation -- the so-called capital gains. One contribution of this paper is to show that while the nominal internal own rate of return specification (M2) appeared to exclude capital gains, in fact it is numerically equivalent to a rental price formula in which asset-specific capital gains were replaced with the average capital gain over all assets. Hence this alternative is consistent with the strong theoretical result that capital gains should be reflected in the rental price estimate of capital service prices.

The empirical analysis of the alternative rental price estimates of capital service prices employs a common data set covering twenty-one two-digit U.S. manufacturing industries over the 1948-1981 period, where each industry purchases from ten to twenty distinct types of capital assets. Our approach is to calculate the aggregate capital rental prices for each formula described in Table 5, and to compare the results based on three characteristics including the ratio of economic and physical aggregate capital services (composition effect), average year-to-year variability in aggregate capital rental prices

(volatility), and percentage of aggregate rental prices with negative estimated values (percent negative).

The most important conclusion from this empirical analysis is that there are significant differences in the three measures we employ in analyzing the five alternative capital rental price formulae. Taking the internal nominal rate of return model (M1) as the benchmark (and eliminating one formula, M5, and two industries, NIPA 15 and 16, for atypical performance), we find that for each of the three measures -- composition effect, volatility, and percent negative -- one or more of the remaining formulas (M2-M4) is statistically significantly different, even after accounting for "time period" effects for the 1965-73 and 1974-81 epochs. Evidently, not only must analysts of U.S. manufacturing industry MFP growth choose amongst at least four alternative capital rental price formulae with little additional help from economic theorists, but at least for U.S. manufacturing, the choice will matter.

Given this conclusion, we offer a number of suggestions for further research. First, for those capital assets that are both purchased and rented (leased) in existing markets, it may be instructive to examine historically the relationship between asset and rental prices, and in particular to determine whether any of the expectations representations are clearly inconsistent with the data. In this way, certain seemingly plausible rental price specifications could be eliminated, and thus the choice of particular specifications in calculating MFP growth rates could be further restricted based on empirical evidence.

Second, the occasional negative property income values for NIPA 15 and 16 (motor vehicles, and transportation equipment excluding motor vehicles) are puzzling, and further analysis needs to be done to interpret and/or revise the underlying data.

Third, our findings suggest that at least three viable alternatives to the standard nominal internal rate of return specification (M1) are available -- nominal internal smoothed (M4), nominal internal own (M2), and possibly in special cases, the constant external real (M3). Because it accounts for asset-specific capital gains, we have a subjective preference for the nominal internal smoothed alternative, but believe further comparative empirical work may be fruitful. In particular, specifications other than the simple three-year moving average procedure merit examination; an obvious possibility is the estimation and implementation of ARIMA models for the expected capital gains component of each of the twenty types of capital plant and equipment.

Fourth, if one wishes to maintain the instantaneous capital adjustment assumption underlying the rental price formulations considered here, we do not understand why separate nominal rates of return are computed for each industry; a priori, instantaneous adjustment could be argued to generate equality in these rates of return. Hence, in future empirical research it might be useful to determine whether equality in industry rates of return changes the capital composition, volatility and percent negative results in any systematic manner. [13]

Fifth and finally, we believe the research presented here highlights conceptual and empirical difficulties encountered when one equates ex ante with ex post rates of return in a model with instantaneous adjustment of capital. Following recent analytical developments by Berndt-Fuss, Hulten and Morrison in specifying models for productivity measurement that distinguish temporary from full equilibrium, we believe future empirical research comparing, among other attributes, the composition, volatility and percent negative characteristics of alternative instantaneous adjustment and short-run, long-run productivity measurement models would be particularly informative and useful.

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FOOTNOTES

[1]In fact, the effect of a capital gains adjustment may actually cause rental price estimates to be negative in periods of rapid inflation, such as those experienced in the U.S. during 1974-1981. This question of negative rental price estimates is an important feature in our evaluation of alternative rental price formulae.

[2]The importance for MFP growth analysis of properly measuring capital service input prices and quantities is suggested by the fact that for the post WW-II period, capital value share in aggregate U.S. manufacturing averaged 15-20% of value added output, and 4-8% of gross output.

[3]Hereafter we employ the term rental price of capital, for at least since Keynes (see the appendix to his General Theory, chapter 6) the user cost notion has also incorporated effects of variations in utilization or intensity of use. While such utilization issues are important, they are not addressed in this paper.

[4]See Hulten-Wykoff [1980] for yet another alternative discrete time formulation that yields a rental price formula very similar to that of Diewert.

[5]As is noted in Diewert [1980, fn. 57], in the limiting case of a nondurable good when $\delta=1$, the Diewert formulation has the attractive property that $q_t = p_t$ (the rental price and asset price are equal), whereas the Christensen-Jorgenson specification yields $p_t = (1+r_t) \cdot q_{t-1}$ (a relationship whose interpretation is unclear).

[6]See Caves, Christensen and Diewert [1982] for further discussion.

[7]When the capital aggregate quantity index is computed using (26), the implicit aggregate capital rental price can be computed using (27).

[8]Following Jorgenson-Sullivan [1981] and Hulten-Robertson [1981], we use the maximum statutory corporate tax rate as most representative of the effective marginal tax rate.

[9]Note that using this r_n measure in the rental price formula is appropriate only if, among other assumptions, capital is instantaneously adjustable. But if capital is adjustable, then its after-tax rate of return should be equal for all sectors of the economy. To the best of our knowledge, this constraint is seldomly imposed in the empirical literature.

[10]The sample correlation coefficient between the rate of return and capital gains components of $p_{i,n}$ is -0.796, while that between the capital gain component and the nominal rate of return (the last column of Table 2) is -0.331.

[11]More general models relating to productivity measurement are, of course, possible. See Berndt-Fuss [1986] for a model in which the full equilibrium assumptions underlying equation (9) are relaxed.

[12]While useful for comparative purposes, it is impossible within our present framework to state whether particular values of the volatility statistic are "reasonable, excessive or insufficient". The difficulty arises due to the full

equilibrium assumptions underlying equation (9) which require that the rental price of capital equal the value of its marginal product. If capital is not sufficiently adjustable (due to its durability and to adjustment costs), then the underlying data will incorporate these disequilibrium effects. For discussions of capital and multifactor productivity measurement that distinguish partial from full equilibrium, see Berndt-Fuss [1986], Hulten [1986] and Morrison [1986].

[13]One possibility here is to define capital income as net of capital gains, compute aggregate rates of return as equal across all industries, and then allow industry-specific capital gains income and capital gains components in the rental price formula.

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DATA APPENDIX

The data used in this study are part of a BLS project to develop

multifactor productivity growth measures for two-digit manufacturing industries.

A preliminary description of this data effort is provided in Gullickson-Harper

[1986]. In general, capital income data are taken from the U. S. Department of

Commerce National Income and Product Accounts (NIPA), while capital stock data

are based on computer tape data underlying estimates of investment and service

lives of various capital types by two digit industry as reported by Gorman,

Musgrave, Silverstein and Comins [1985] and Musgrave [1986]. We are grateful to

these authors for making this detaileddata available. Capital stocks have been

constructed using the perpetual inventory method and age-efficiency functions

which imply that services decline slowly during the early years of the life of

an asset. The hyperbolic efficiency functions employed are identical to those

specified in Appendix C of Bureau of Labor Statistics [1983].

Estimates of capital income are based on the NIPA. Capital income is equal

to industry current dollar gross product originating except for labor

compensation (wages, salaries, supplementary compensation, and a portion of

proprietors' income). Hence capital income consists of before tax corporate

profits, net interest payments, capital consumption allowances, subsidies,

indirect taxes, transfers, and the portion of proprietors' income not attributed

to labor.

The remaining elements of the rental price expressed are determined as

follows. Given the hyperbolic efficiency function, the rate of economic

depreciation is derived based on the duality between the efficiency of an asset

and its price, as discussed in Harper [1982]. Deflators for new investment

goods by asset type are calculated as the ratio of investment in current dollars

to investment in constant dollars, as reported in NIPA. Tax rate parameters are formulated based on estimated marginal incentives rather than effective average rates. In particular, following Jorgenson-Sullivan [1981] and Hulten-Robertson [1981], we employ the maximum statutory corporate tax rate as the estimate of the marginal tax rate; further discussion on this tax issue is also found in Brandford-Fullerton [1981]. As estimates of the present value of one dollar's worth of depreciation allowances, and for the effective rate of the investment tax credit, we employed values computed for the published BLS [1983] major sector measures. Finally, for the rate of indirect taxation, we divided NIPA estimates of indirect taxes by the estimated capital stock.

Table 1

Measures Related to Multifactor Productivity Growth
U.S. Private Business Sector
Percent Change at a Compound Annual Rate

Time Span	Multi-factor Product-ivity	Output	Capital Product-ivity	Capital Input	Capital Stock	Compos-ition Effect
1948-1984	1.5	3.4	0.0	3.4	2.6	0.8
1948-1973	2.0	3.7	0.2	3.6	2.6	0.9
1973-1981	0.1	2.2	-1.1	3.4	2.8	0.6
1981-1984	1.8	3.5	1.2	2.3	2.1	0.2

Source: Bureau of Labor Statistics (1985)

Table 2

Miscellaneous Manufacturing Industries
Asset: Metalworking Machinery
Internal Nominal Rate Of Return Model

Year	Share	Rental Price	Additive Contributions to Rental Price				Nominal Rate of Return
			Rate of Return	Deprec-iation	Capital Gains	Indirect Taxes	
1971	0.1301	0.2622	0.1529	0.1386	-0.0350	0.0056	0.1160
1972	0.1290	0.2856	0.1723	0.1395	-0.0331	0.0068	0.1281
1973	0.1608	0.3180	0.2095	0.1426	-0.0413	0.0071	0.1502
1974	0.2475	0.3332	0.3010	0.1608	-0.1362	0.0075	0.1921
1975	0.0799	0.2065	0.3089	0.1989	-0.3117	0.0104	0.1636
1976	0.1273	0.3118	0.2051	0.2024	-0.1084	0.0127	0.1035
1977	0.1265	0.3449	0.2947	0.2237	-0.1872	0.0138	0.1371
1978	0.1840	0.4204	0.3437	0.2493	-0.1883	0.0156	0.1463
1979	0.2318	0.5169	0.4697	0.2776	-0.2484	0.0180	0.1799
1980	0.2390	0.5827	0.5730	0.3296	-0.3436	0.0238	0.1876
1981	0.0838	0.3589	0.2950	0.3370	-0.3065	0.0334	0.0970
Mean	0.1582	0.3583	0.3024	0.2182	-0.1763	0.0141	0.1456
Std. Dev.	0.0571	0.1051	0.1208	0.0696	0.1102	0.0081	0.0314

TABLE 3

Miscellaneous Manufacturing Industries
Asset: Metalworking Machinery
Internal Own Rate Of Return Used

| Year | Share | Rental Price | Additive Contributions to Rental Price | | | | Own Rate of Return |
			Rate of Return	Deprec- iation	Capital Gains	Indirect Taxes	
1971	0.1256	0.2532	0.1090	0.1386	0.0000	0.0056	0.0826
1972	0.1227	0.2717	0.1254	0.1395	0.0000	0.0068	0.0932
1973	0.1283	0.2536	0.1039	0.1426	0.0000	0.0071	0.0745
1974	0.1579	0.2127	0.0443	0.1608	0.0000	0.0075	0.0283
1975	0.1401	0.3622	0.1529	0.1989	0.0000	0.0104	0.0810
1976	0.1494	0.3659	0.1508	0.2024	0.0000	0.0127	0.0761
1977	0.1535	0.4184	0.1810	0.2237	0.0000	0.0138	0.0842
1978	0.1707	0.3899	0.1249	0.2493	0.0000	0.0156	0.0532
1979	0.1800	0.4013	0.1057	0.2776	0.0000	0.0180	0.0405
1980	0.1895	0.4619	0.1085	0.3296	0.0000	0.0238	0.0355
1981	0.1535	0.6571	0.2866	0.3370	0.0000	0.0334	0.0943
Mean	0.1519	0.3678	0.1357	0.2182	0.0000	0.0141	0.0676
Std. Dev.	0.0210	0.1192	0.0582	0.0696	0.0000	0.0081	0.0227

TABLE 4

Miscellaneous Manufacturing Industries
Asset: Metalworking Machinery
External Nominal Rate Of Return (Moody's Baa Bond Yield) Model

| Year | Share | Rental Price | Additive Contributions to Rental Price | | | | Moody Baa Rate | Ratio Ex Post to Ex Ante Income |
			Rate of Return	Deprec- iation	Capital Gains	Indirect Taxes		
1971	0.1487	0.2997	0.1523	0.1870	-0.0472	0.0076	0.0856	1.3492
1972	0.1589	0.3518	0.1732	0.2201	-0.0522	0.0107	0.0816	1.5772
1973	0.2799	0.5535	0.2848	0.3534	-0.1024	0.0176	0.0824	2.4780
1974	-0.3322	-0.4473	-0.3678	-0.3973	0.3363	-0.0185	0.0950	-2.4700
1975	0.0734	0.1898	0.3884	0.3856	-0.6042	0.0201	0.1061	1.9389
1976	0.1399	0.3425	0.2206	0.2312	-0.1238	0.0145	0.0975	1.1424
1977	0.1469	0.4006	0.3178	0.3687	-0.3086	0.0227	0.0897	1.6483
1978	0.2756	0.6294	0.4684	0.5237	-0.3955	0.0328	0.0949	2.1004
1979	0.9271	2.0676	1.7686	1.7591	-1.5744	0.1143	0.1069	6.3375
1980	0.5222	1.2731	1.2441	0.9818	-1.0238	0.0709	0.1367	2.9791
1981	0.0952	0.4075	0.3603	0.2490	-0.2265	0.0247	0.1604	0.7389
Mean	0.2214	0.5517	0.4555	0.4420	-0.3748	0.0288	0.1034	1.8018
Std. Dev.	0.2955	0.6138	0.5488	0.5178	0.5040	0.0338	0.0233	1.9683

Table 5

Summary of Alternative Capital Rental Price Characteristics

Model	Description	Capital Gains	Rate of Return
M1	Internal Nominal Rate of Return (Jorgenson-Siebert [1968a,b], Christensen-Jorgenson [1969],Fraumeni-Jorgenson [1980], BLS [1983, Except Agriculture].	Asset Specific Appreciation, Perfectly Realized.	From Capital Income Identity.
M2	Internal Own Rate of Return (Jorgenson-Siebert [1968a,b].	Average Asset Appreciation, Perfectly Realized.	From Capital Income Identity.
M3	Constant External Own Rate (Hall-Jorgenson [1968], Hall-Jorgenson [1969], Coen [1975], BLS]1983, Agriculture]).	Average Asset Appreciation, Perfectly Realized.	Constant Nominal Rate (=3.5%).
M4	Internal Nominal Rate of Return with Smoothed Capital Gains (Similar in Concept to Epstein [1977], Gillingham [1980]).	Asset Specific Appreciation, expected.	From Capital Income Identity.
M5	External Nominal Rate of Return (Coen [1968], Eisner [1969], Evans [1967], Grunfeld [1960], Holland-Myers [1979], Miller-Modigliani [1966].	Asset Specific Apprecition, Perfectly Realized.	External Rate, Moody Baa Bond Rate.

Table 6

A Comparison of Methods of Computing Rental Prices for Two-Digit Manufacturing Industries 1948-1981

NIPA Industry	Internal Nominal Rate of Return Model (M1)			Internal Own Rate of Return Model (M2)			External Own Rate of Return Model (Constant 3.5%) (M3)			Internal Nominal Rate Calculated with Smoothed Capital Gains (M4)			External Nominal Rate of Return Model Using Moody's Baa Bond Rate (M5)		
	Composition Effect	Volatility Stat.	Percent Negative	Composition Effect	Volatility Stat.	Percent Negative	Composition Effect	Volatility Stat.	Percent Negative	Composition Effect	Volatility Stat.	Percent Negative	Composition Effect	Volatility Stat.	Percent Negative
8-Lumber & Wood	0.032	0.291	0.0	0.001	0.185	0.0	0.187	0.184	0.0	0.015	0.204	0.6	3.671	1.045	5.0
9-Furniture & Fixt.	-0.016	0.267	0.2	0.002	0.150	0.0	-0.161	0.147	0.0	0.097	0.179	0.5	-0.168	0.728	3.0
10-Stone Clay Glass	-0.001	0.236	2.2	-0.024	0.138	0.9	-0.085	0.138	0.0	0.024	0.151	1.7	0.051	183.114	3.5
11-Primary Metals	0.152	0.424	2.7	0.106	0.185	0.0	0.006	0.178	0.0	0.120	0.230	2.0	0.895	6.799	6.2
12-Fabr. Metal Prod.	0.142	0.277	0.6	0.160	0.121	0.0	0.137	0.119	0.0	0.217	0.140	0.4	-17.626	9.004	3.7
13-Mach. Except El.	0.455	0.170	0.0	0.221	0.111	0.0	0.252	0.110	0.0	0.417	0.118	0.2	0.743	3.610	3.9
14-Electrical Mach.	0.083	0.223	0.4	0.070	0.161	0.0	-0.153	0.161	0.0	0.138	0.168	0.4	-0.248	0.326	1.2
15-Motor Vehicles	0.393	0.472	2.8	0.393	0.484	2.4	0.206	0.623	0.0	0.419	0.477	2.8	0.221	0.730	1.1
16-Other Transp Eqp.	-10.871	-0.054	7.3	-11.091	-0.199	4.0	-0.109	0.237	12.1	-11.093	-0.236	6.5	1.069	0.868	16.2
17-Instruments	0.069	0.441	0.2	-0.131	0.131	0.0	-0.164	0.130	0.0	-0.008	0.138	0.5	-0.190	0.650	2.8
18-Miscellaneous Mfg	0.464	0.410	0.9	0.265	0.173	0.0	0.106	0.166	0.0	0.562	0.596	0.5	-1.638	59.861	5.6
19-Food	0.112	0.194	0.5	-0.028	0.073	0.0	-0.078	0.070	0.0	0.097	0.104	0.2	0.060	0.276	0.5
20-Tobacco	0.433	0.062	0.0	0.435	0.056	0.0	-0.051	0.052	0.0	0.427	0.056	0.0	-0.054	0.052	0.0
21-Textile	0.128	0.459	5.3	0.011	0.189	3.0	0.002	0.167	0.0	0.283	0.192	3.3	-12.856	0.576	3.5
22-Apparel	-0.255	0.328	0.7	-0.189	0.173	0.0	-0.179	0.166	0.0	-0.152	0.185	0.5	0.115	487.091	2.6
23-Paper	-0.145	0.231	0.2	-0.104	0.111	0.0	-0.112	0.110	0.0	-0.078	0.135	0.6	18.466	0.744	3.8
24-Printing	-0.008	0.169	0.0	-0.030	0.100	0.0	-0.057	0.095	0.0	0.112	0.129	0.3	-0.273	61.024	3.8
25-Chemicals	0.204	0.174	1.2	0.067	0.094	0.0	0.022	0.091	0.0	0.220	0.121	0.4	0.124	0.773	3.9
26-Petroleum	-0.074	0.371	4.2	-0.096	0.181	1.3	-0.148	0.179	0.0	-0.127	0.222	3.4	-0.076	0.405	2.4
27-Rubber	-0.044	0.459	3.0	0.007	0.151	1.9	-0.065	0.151	0.0	0.033	0.163	3.3	-0.197	0.529	1.9
28-Leather	0.329	0.664	2.8	-0.001	0.372	0.0	-0.017	0.339	0.0	0.227	0.420	0.8	-7.474	Overflow	5.8

Table 7

Summary of Models Used To Compute Capital Rental Prices
Simple Averages of Statistics Over Nineteen of Twenty-One
Two-Digit U.S. Manufacturing Industries

Time Period	Rate of Return Used in Model			
	Internal Nominal (M1)	Internal Own (M2)	External Own (3.5%) (M3)	Internal Nominal Smoothed (M4)
	Composition Effect			
1948-1981	.108	.039	-.029	.138
1948-1965	.016	-.033	-.071	.065
1966-1973	.149	.105	.067	.116
1974-1981	.266	.128	-.037	.315
	Volatility Statistic			
1948-1981	.308	.150	.145	.192
1948-1965	.282	.149	.144	.162
1966-1973	.174	.122	.116	.135
1974-1981	.498	.180	.175	.314
	Percent of Rental Prices Negative			
1948-1981	1.3	0.4	0.0	1.0
1948-1965	0.5	0.2	0.0	0.8
1966-1973	0.6	0.0	0.0	1.0
1974-1981	3.9	1.0	0.0	2.3

Table 8

Summary of Effects of Alternative Capital Rental Price Measures
Ordinary Least Squares Regression with data from
Three Time Periods, Four Models and Nineteen of Twenty-One
Two-Digit U.S. Manufacturing Industries
(Estimated Standard Error in Parentheses)

Dependent Variable:	Composition Effect (i)	(ii)	Volatility Effect (i)	(ii)	Percent Negative (i)	(ii)
Constant*	.047	.016	.298	.282	.012	.005
	(.040)	(.057)	(.028)	(.038)	(.003)	(.004)
M2 Dummy	-.077	-.049	-.167	-.133	-.012	-.002
	(.047)	(.080)	(.032)	(.054)	(.004)	(.006)
M3 Dummy	.022	.050	-.114	-.120	-.006	.036
	(.047)	(.080)	(.032)	(.054)	(.004)	(.004)
M4 Dummy	-.157	-.087	-.173	-.138	-.017	-.005
	(.047)	(.080)	(.032)	(.054)	(.004)	(.006)
1966-73 Dummy	.115	.133	-.047	-.107	-.002	.002
	(.040)	(.080)	(.028)	(.054)	(.003)	(.006)
1974-81 Dummy	.174	.250	.108	.216	.014	.034
Dummy	(.040)	(.080)	(.028)	(.054)	(.003)	(.006)
Interaction Terms						
M2•1966-73 Dummy		.005		.081		-.004
		(.113)		(.076)		(.009)
M3•1966-73 Dummy		-.083		.081		-.009
		(.113)		(.076)		(.009)
M4• 1966-73 Dummy		.005		.079		-.002
		(.113)		(.076)		(.009)
M2•1974-81 Dummy		-.089		-.184		-.026
		(.113)		(.076)		(.009)
M3•1974-81 Dummy		.000		-.064		-.019
		(.113)		(.076)		(.009)
M4•1974-81 Dummy		-.215		-.185		-.034
		(.113)		(.076)		(.009)
Mean of Dependent Variable:	.090	.090	.204	.204	.008	.008
Standard Error of Regression:	.249	.248	.170	.166	.020	.019

*The constant term is interpreted as the mean for the standard internal nominal
rate of return model over the 1948-65 time period.

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